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An Open-Source Tool for Energy Storage Sizing and Placement in Electric Grids QuESt-SSIM

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Presentation Outline

- Need and objectives
- Tool architecture
- Tool usage
- Example case study
  - Demonstrate tool for sizing and placement for voltage regulation in a distribution system
- Conclusions and Future Work

Motivation / Need

- Energy storage systems (ESSs) have the potential to:
  - Enhance the operation and value of grid resources
  - While improving system resilience and reliability against threats
- Advanced engineering tools required
  - Enable stakeholders to make informed decisions regarding deployment of energy storage
- Guide decisions on various configurations of ESSs including their size, location and control/operating strategy incorporating considerations of:

Grid Physics

Disruptions caused by extreme events

Coupling of Interdependent Systems across Multiple Timescale and Domains

Sources:
- *U.S. Department of Energy, "Energy Storage Grand Challenge Roadmap," 2020.*
- *R. Bent, W. Du, M. Heleno, R. Jeffers, M. Korkali, G. Liu, D. Olis, P. Pradhan and R. Singh, "Integrated Models and Tools for Microgrid Planning and Designs with Operations," 2022*

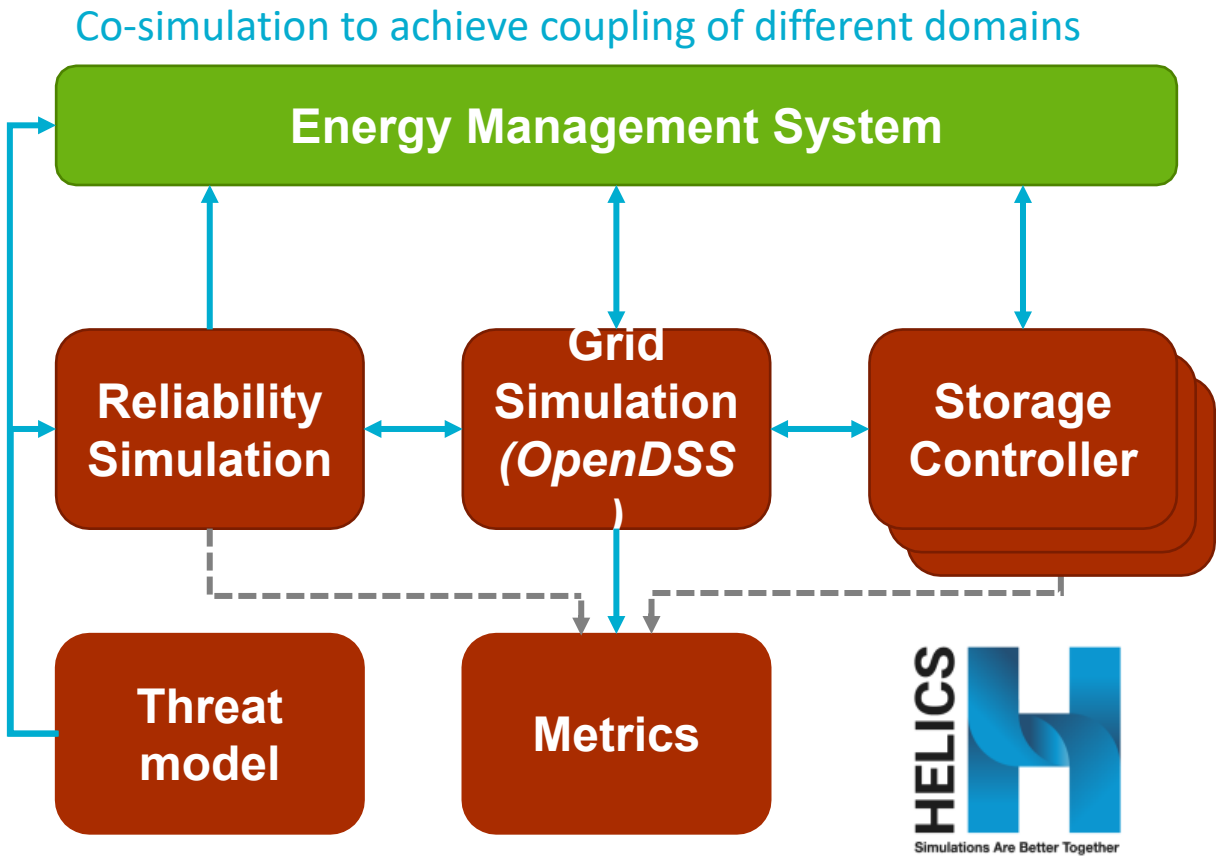
Objectives

QuESt-SSIM- Develop an open-source python-based simulation capability

1. **Discrete event simulation with physics-based grid models**
   - Accurately evaluate the impact of energy storage on distribution grids
2. **Flexible architecture**
   - Support simulations across multiple domains and timescales
   - Weather, reliability, and energy storage among other components
3. **Support optimization over multiple objectives**
4. **Optimize energy storage controls/operating strategy as well as size and placement**

Architecture of QuESt-SSIM

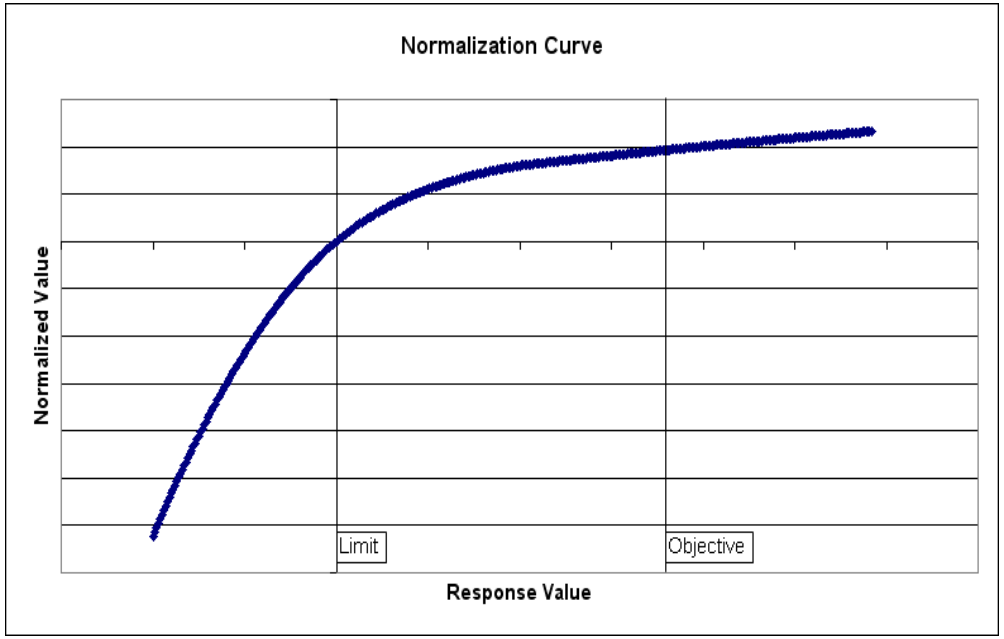
- HELICS is used to couple several simulations
  - Co-simulation framework that allows simulators of different domains to exchange information during run-time
  - Allowing larger and complex simulations
- Current simulation capabilities
  - OpenDSS grid simulation
  - Grid reliability simulation
  - Multiple storage controller simulation
  - Energy management system simulation
  - A threat simulation
  - Metrics aggregation



Metrics-based Approach to Quantify Performance

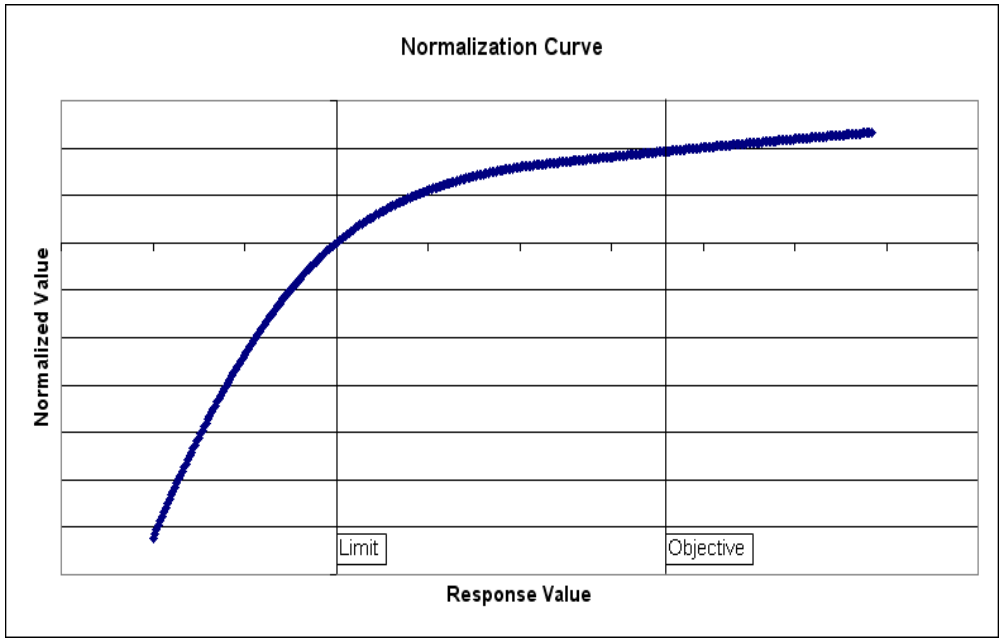
- Grid simulation is configured to report measurements at specific locations to a “metrics federate”

- Each measured value is assigned :
  - target values (limit and objective)
  - an improvement type (minimize, maximize, seek-value).



Metrics-based Approach to Quantify Performance

- Metrics federate normalizes the values it receives using a non-linear normalization curve
  - Allows different quantities of interest to be compared directly.



For example, we can examine trade offs between voltage across the grid, line loading, energy service, or any other quantity of interest.

Tool Usage

Through Command Line Interface

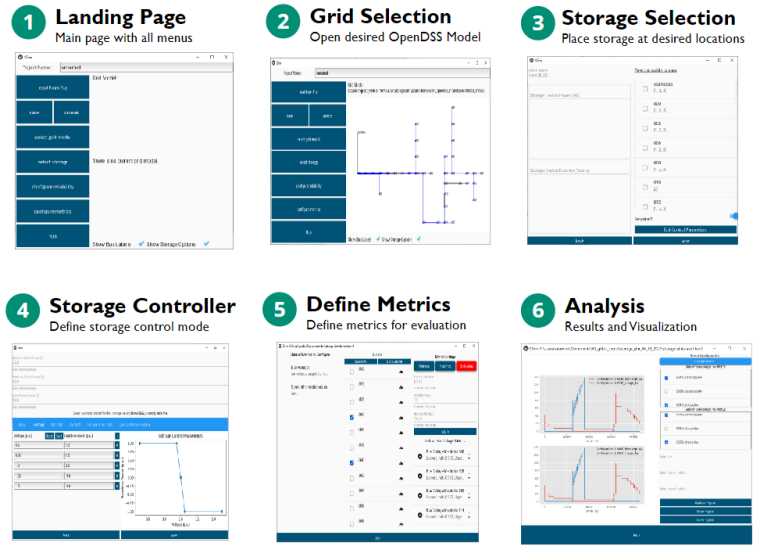
- Setup simulator using configuration files
- JSON-based configuration for human readability
- Allows for high degree flexibility

```
"dss_file": "../ieee34demo/ieee34Mod_temp.dss",
"busses_to_log": ["814", "828", "860", "840"],
"busses_to_measure": [
    {"name": "814", "objective": 1.0, "limit": 0.975},
    {"name": "828", "objective": 1.0, "limit": 0.975},
    {"name": "860", "objective": 1.0, "limit": 0.975},
    {"name": "840", "objective": 1.0, "limit": 0.975}
],
"storage": [
    {
        "name": "S814",
        "bus": "814",
        "phases": 3,
```

QuESt-SSIM
https://github.com/sandialabs/quest-ssim

GUI through Sandia's QuESt Platform

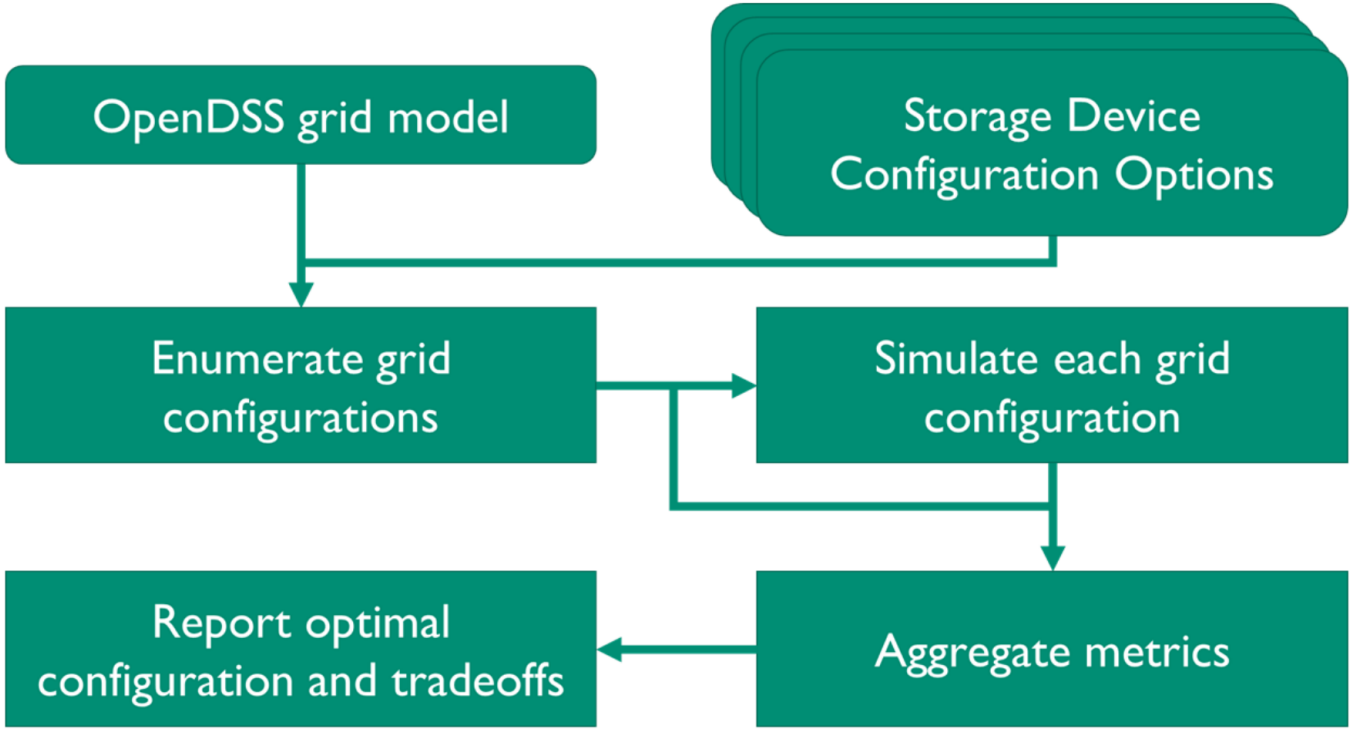
- User friendly interface
- Provides a simple entry point



QuESt 2.0 Download
https://www.sandia.gov/ess/tools-resources/quest

Using QuESt-SSIM

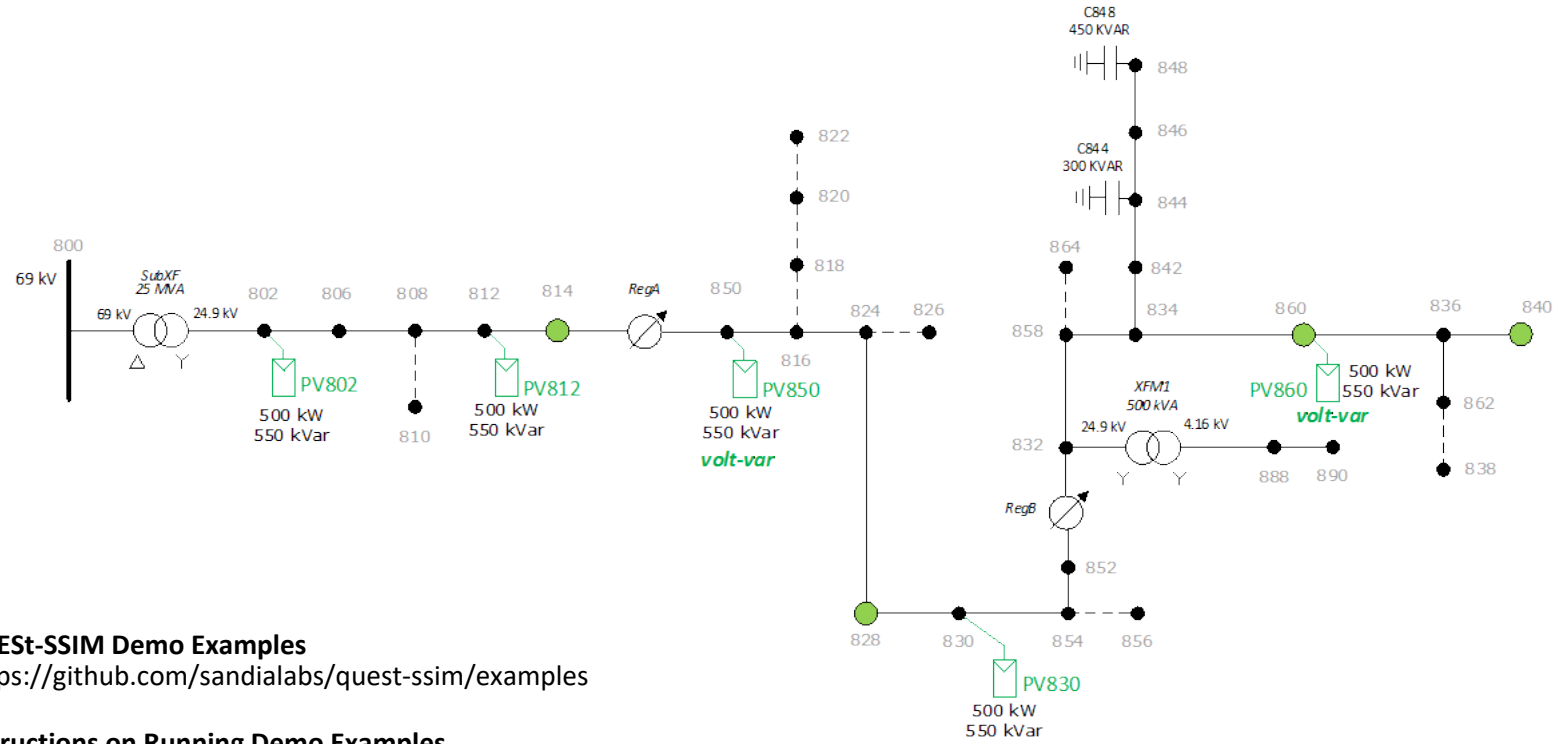
Workflow in QuESt-SSIM



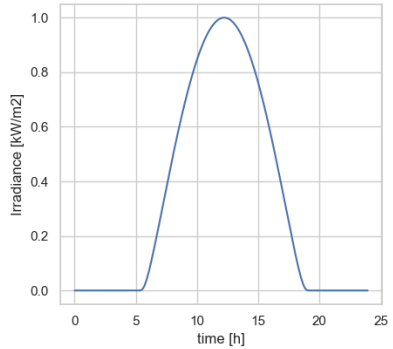
Example Case Study Setup

- Busses 814, 828, 860, 840 are assumed “critical”
  - Allowed voltage range of 0.975 – 1.025 pu
  - Arbitrary assumptions for demonstration

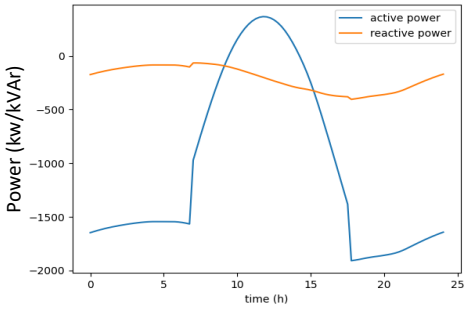
Question: What would the size of storage required and where should it be placed?



Test Irradiance Profile



Load Demand
(Measured at Substation)

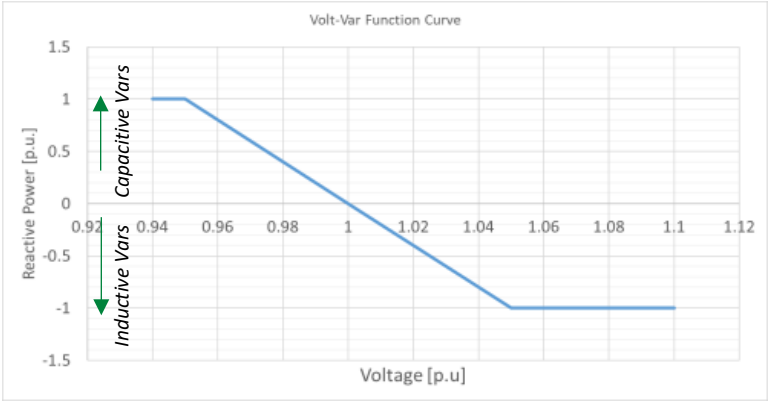


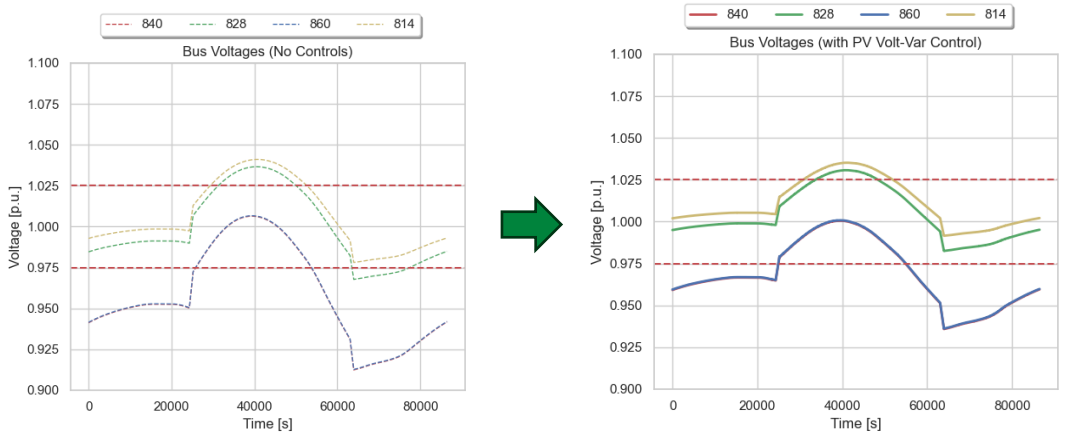
QuESt-SSIM Demo Examples
https://github.com/sandialabs/quest-ssim/examples

Instructions on Running Demo Examples
https://sandialabs.github.io/quest-ssim/demo_examples.html

Impact of Volt-Var Function from PV

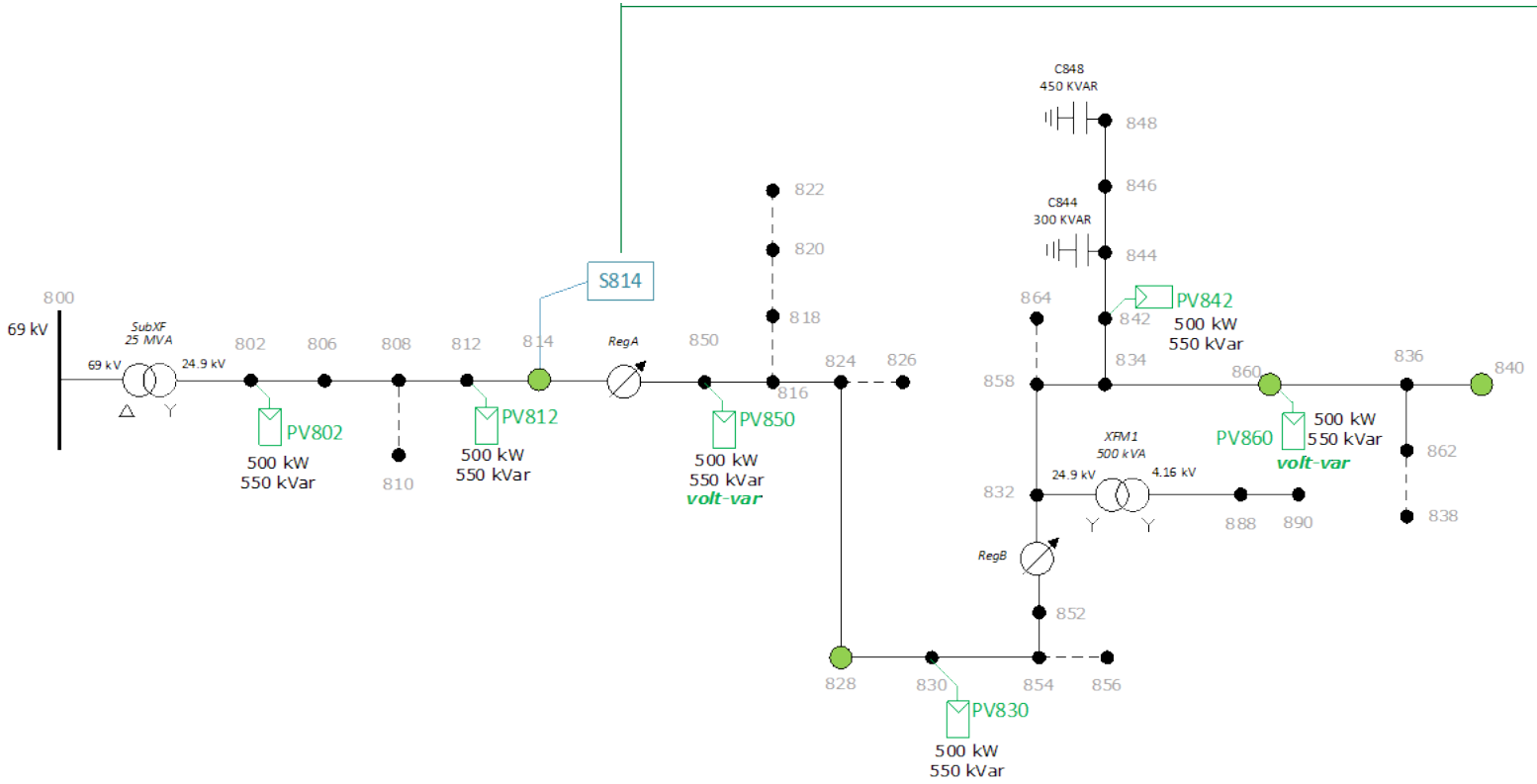
- According to IEEE 1547-2018 standard for interconnection of DERs, PV inverters need to provide grid support functions such as volt-var
- Simulator has the ability to enable such inverter functions
- PVs 850 and 860 are assumed to be capable of providing volt-var support
    - Other PV units operating with MPPT injecting all the available active power



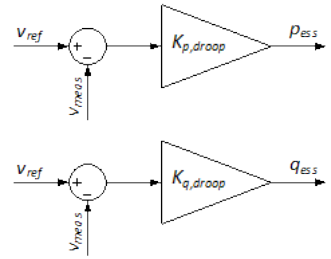


Volt-var functions provide some level of voltage regulation – not enough on its own.

Configuration 1



Droop Controller

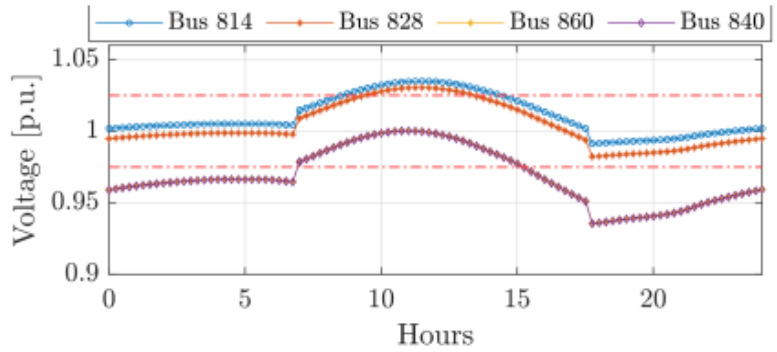


- Single energy storage unit placed at Bus 814 for voltage regulation
- Droop-based control based on voltage measured at Bus 814
  - Relatively high droop-gains where used to achieve desired voltage regulation

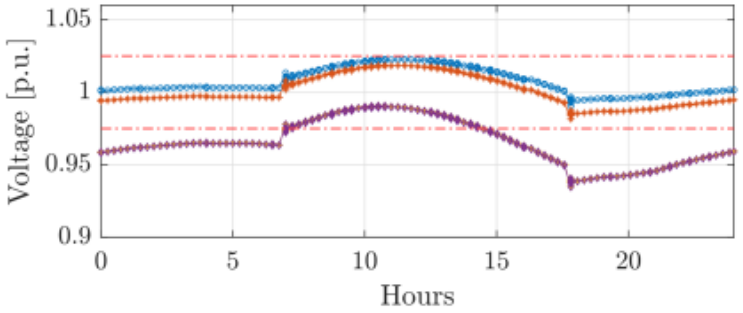
Configuration 1

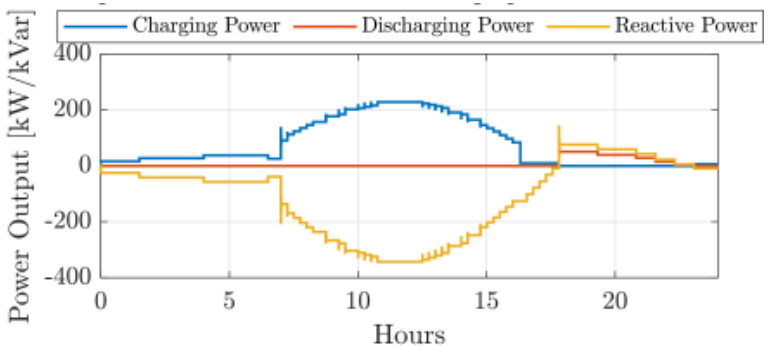
1 - Storage Unit Placed Near Substation

Without Energy Storage



With Energy Storage at Bus 814



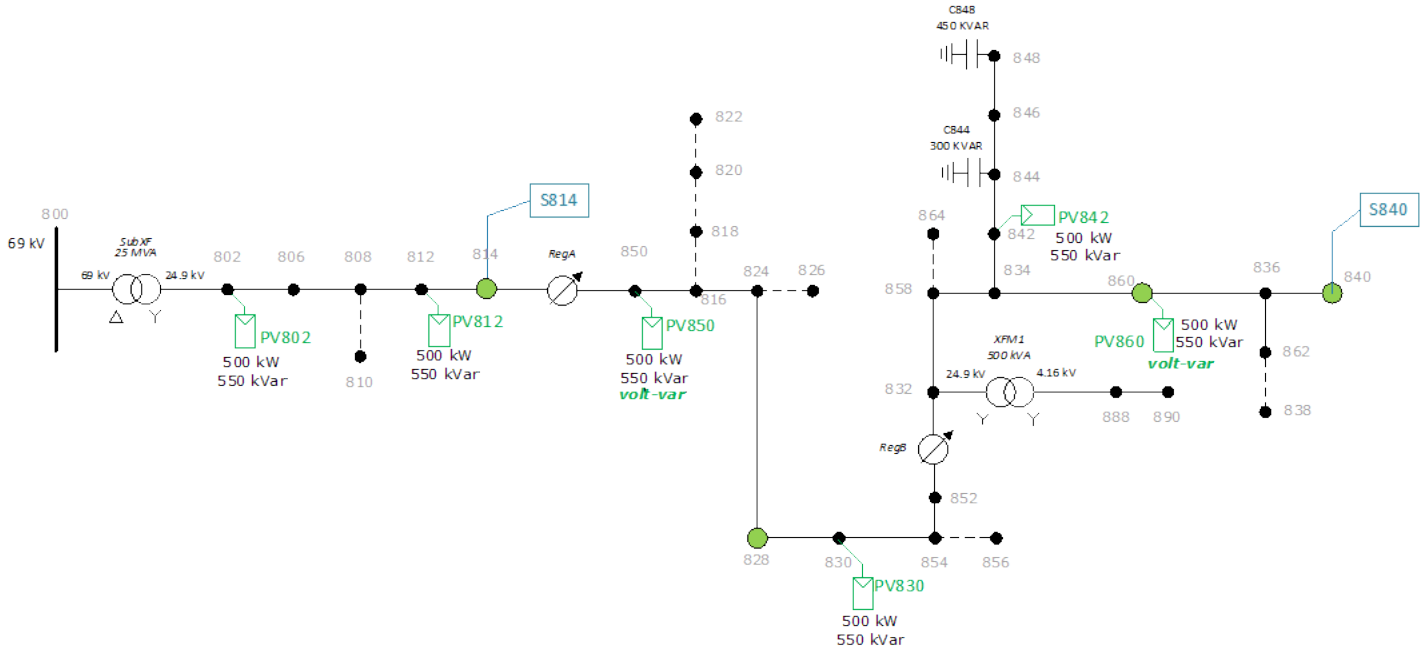


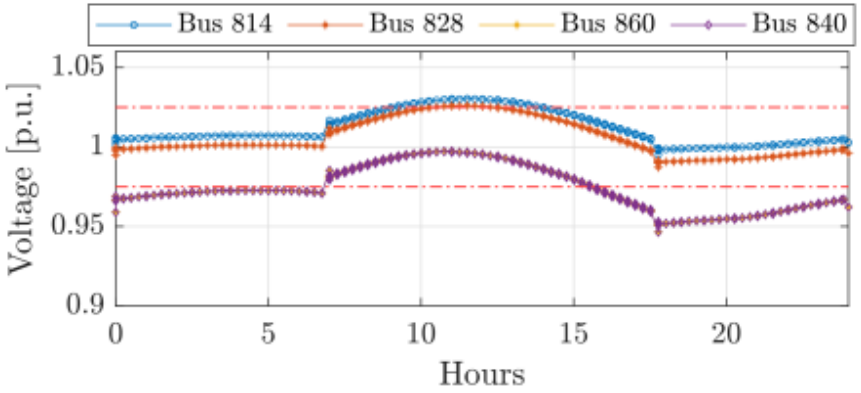
Storage Requirements
450 kW, 500 kVA
~1500 kWh

- Storage requirements calculated based on peak active and reactive power
- Overvoltage has been limited to within desired limits
- Undervoltage is still an issue with this configuration

Configuration 2

Additional Storage Unit Placed at End of the Feeder



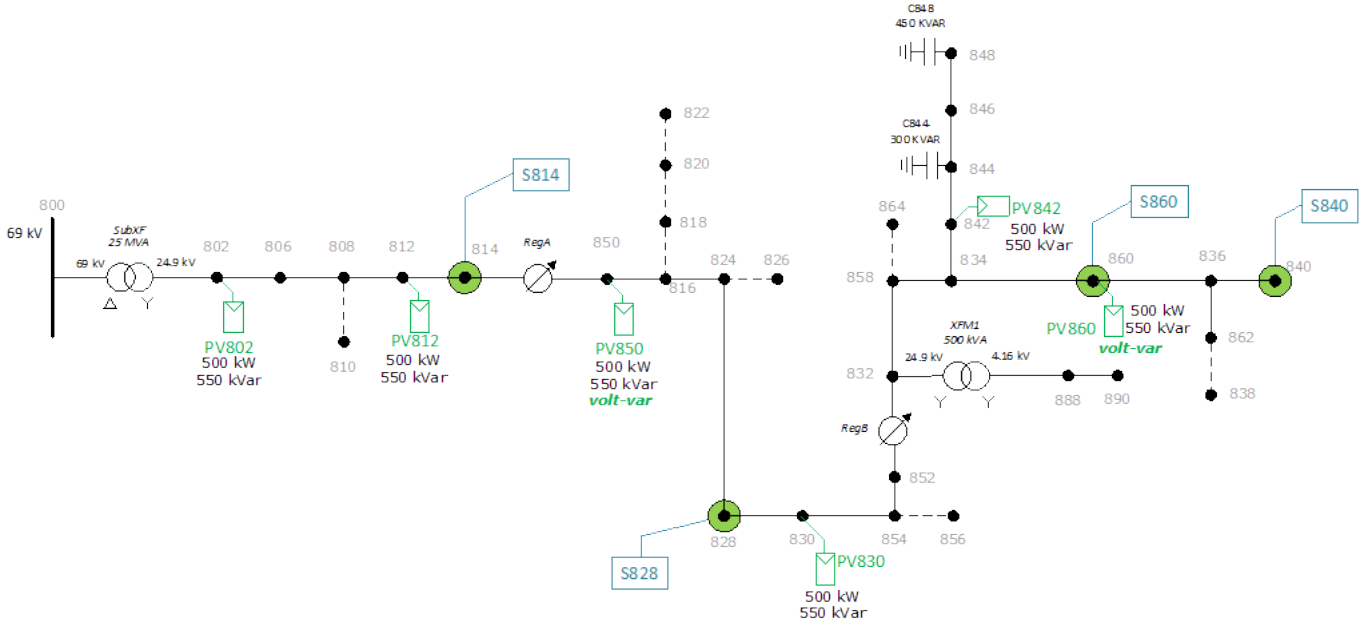


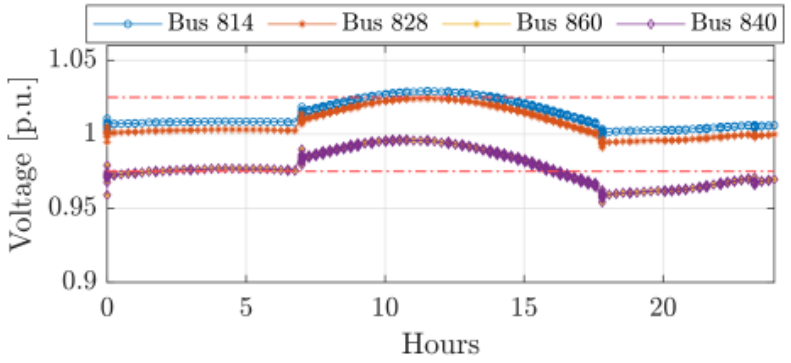
- Voltage nearly within desired limits with two storage units

	kW, kVA Requirement	kWh Requirement
S814	175 kW, 200 kVA	1800 kWh
S840	250 kW, 275 kVA	750 kWh

Configuration 3

4-Smaller Distributed Units at Each Critical Bus



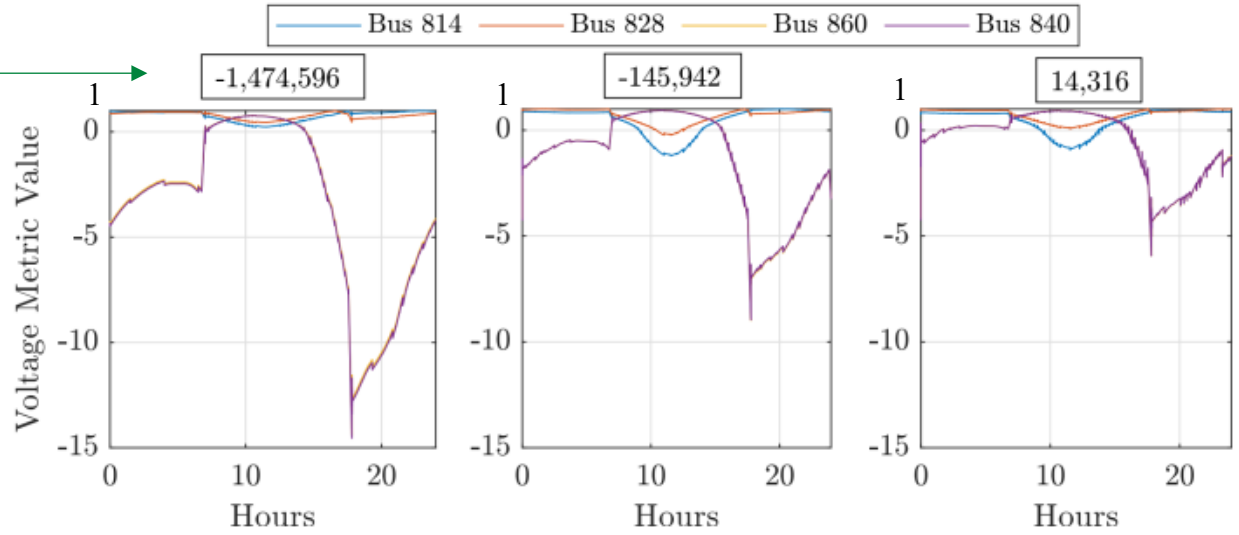


	kW, kVA Requirement	kWh Requirement
S814	150 kW, 175 kVA	650 kWh
S828	150 kW, 175 kVA	350 kWh
S840	250 kW, 275 kVA	1500 kWh
S840	250 kW, 275 kVA	1500 kWh

- Slightly improved voltage regulation compared to Configuration 2

Metrics-based Comparison

Accumulated Metric



Configuration 1 | Configuration 2 | Configuration 3

- Ideally this metric should be at 1.0
  - Approaches 0 as the value deviates from the target
  - As the value drifts beyond the limits, the metric takes negative values
- Configurations 2 and 3 seem to provide identical performance
  - Accumulated metric show Configuration 3 is somewhat better for voltage regulation

Conclusions

- Introduced QuEST-SSIM – an open-source python-based simulation capability
  - Guides decisions on various configurations of ESSs including their size, location and control/operating strategy
- Demonstrated the tool's capabilities for voltage regulation application
- Metrics-based quantification aids in decision making

Future Development Plans

- Ability to model different storage technologies
- Optimization algorithm is in the process of being implemented to efficiently navigate the search space
- Expand co-simulation capabilities
  - Simulate non-electrical domains
  - Threat models
- Validate and expand feature through partnered real-world projects in collaboration with relevant stakeholders

Thank You!

- Looking for users to test our tool
- Collaborations to partner and further develop the tool taking into account input from various stakeholders

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